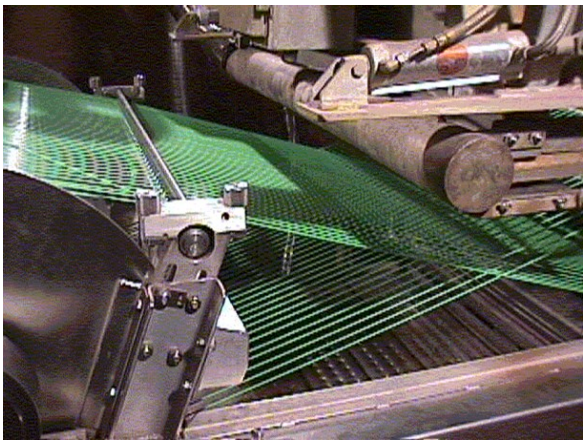
EXRAD® Irradiated XLPE vs. Silicone Automotive Battery Cables



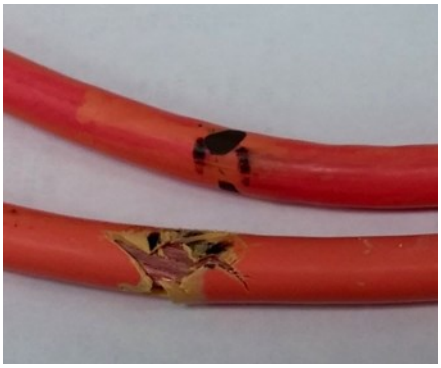
Wire in a typical "figure-8" pattern under an irradiation beam

Irradiation Cross-Linking allows cost effective modification of a wide array of polymers to significantly improve their performance, allowing them to be used in harsh vehicle environments such as temperature extremes, fluid exposure, mechanical stress and other challenging conditions.

Thoughtful polymer formulation and processing techniques can bring about additional features such as flexibility, reduced diameters, longer life, stripping advantages, and other application-specific benefits. EXRAD® irradiated XLPE's are thermo-set materials, which means the molecules are set in place and won't melt if an excessive thermal event occurs.

Silicone Rubber is a thermo-set material also. It has good electrical performance and flexibility characteristics, but also has fundamental deficiencies that make it undesirable in many automotive and commercial vehicle battery cable applications.

Below are some examples of how these deficiencies affect performance.



Top: EXRAD® Bottom: Silicone

Battery Acid Resistance

Specification	EXRAD® HVFX	Silicone Rubber
ISO 6722-1	Passes	Fails

Battery cables are typically in direct contact with batteries and the opportunity for exposure to battery acid must be taken into account.

EXRAD® materials are resistant to battery acid and pass the ISO-6722-1 requirement. Silicone materials react much differently when exposed to battery acid and severe material degradation can occur as reflected in the bottom cable in the picture. During the ISO 6722-1 test procedure the battery acid dissolved the insulation. In service on a vehicle, this poses a significant risk of electrical failure. The EXRAD® cable was barely affected and passes the ISO requirement.

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Outgassing

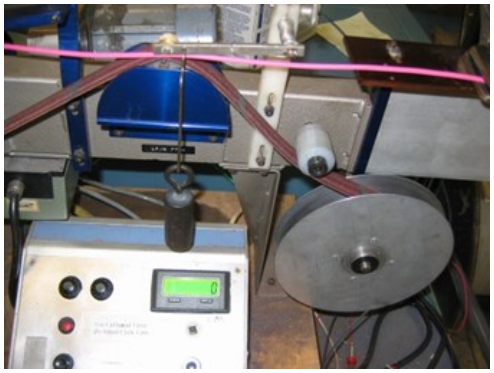
Outgassing is often overlooked as a potential issue, yet can quickly become a serious concern in automotive environments. Outgassing can be initiated by excessive heat generated from processes and applications including but not limited to ultra-sonic welding, applying heat shrink tubing, or exposure in a hot environment such as an engine compartment.

Outgassing is defined as release of gas that was either dissolved or evolves as the temperature is enhanced due to continued reaction. The volatilization could be due to low molecular oils or other chemicals that are left over after polymerization.

Materials (such as copper conductors) that are in close proximity to the outgasses can change their physical, chemical and electrical properties. In addition, the silicone polymer itself can go through changes in its properties such as dielectrics, insulation resistance and mechanical integrity.

Perhaps the biggest concern is how the outgassed materials can degrade electrical contacts rendering them insufficient in the application. Outgassed materials can also affect painting / coating processes causing significant processing malfunction.

EXRAD® XLPE materials are strengthened by E-beam irradiation cure, a known process of robust cross linking due to even penetration of the beam, and there is no outgassing encountered.



Sand Paper Abrasion Test

Specification	EXRAD® HVFX	Silicone Rubber
SAE J-1128	3,270mm	2,581mm

This test simulates the insulation's abrasion resistance to sand and grit. This is an important feature during the operational life of the vehicle. Insulation that abrades more quickly has lower dielectric breakdown resistance and will fail quicker in high voltage applications.

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Strip-ability

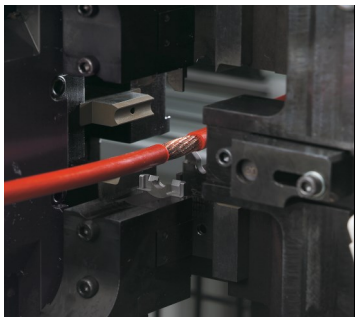

Image courtesy of Mechtrix Corp.

The ability to strip cables cleanly and consistently increases throughput and reduces costs. This is of great concern to the cable assembly provider, and ultimately the OEM.

EXRAD® materials are flexible, yet also cut and strip cleanly. "Pig-tails" are often eliminated, and the insulation strips cleanly leaving a consistent surface for connectorization.

Silicone has high elongation (stretch) which helps flexibility but makes the material difficult to strip cleanly, leaving small sections of insulation un-stripped. (aka pig-tails) To combat this, stripping blades must penetrate the silicone jacket nearly completely, which can cause conductor strands to be cut away. Some customers allow a few cut strands, but others allow none. The goal of eliminating pig-tails while also not cutting strands often slows production considerably.

Another concern is wrinkling or buckling. Silicone insulation tends to buckle on itself during stripping. Once it buckles, it becomes very difficult to remove. Occasionally a paper separator or talc is used to aid in stripping. Neither remedy is ideal. The paper adds another component layer to contend with and talc can affect the stripping equipment.

Dielectric Constant

Parameter	EXRAD® HVFX	Silicone Rubber	Comments
Volume Resistivity @ 20˚C	1×10^{16}	1×10^{15}	Resistance to current leakage

Maintaining consistent dielectric properties of the insulation material is a critical parameter. Materials with low and consistent dielectric constants perform better at keeping current from flowing through the insulation and onto the braid shield or other plane. Materials with higher and inconsistent dielectric constants risk current leakage. Champlain EXRAD® FX, HVFX and ERGOFLEX™ materials have lower and consistent dielectric constants due to polymer formulation and E Beam cross linking.

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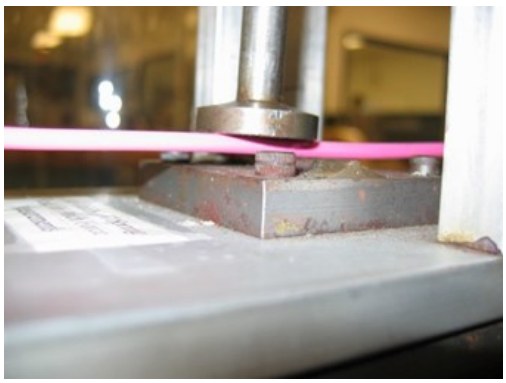

Pinch Test

Specification	EXRAD® HVFX	Silicone Rubber
SAE J-1128	9.8 Kg	1.8 Kg

Automotive and Commercial Vehicle battery cables should be mechanically rugged and robust in order to perform well in their environment.

This pinch test simulates insulation cut-through resistance which is an important feature in the end use application and also during harness installation.

Higher pinch resistance represents reduced wear due to sliding and impact forces. Even minor insulation damage can lead to dielectric failure resulting in a direct electrical short. Pinch resistance is also an important characteristic during the termination process. If a cable has low pinch resistance, it is more prone to splitting when terminated / connectorized.

EXRAD® materials are strong due to a combination of material formulation and E Beam cross linking. Silicone materials are not as resistant to these types of forces.

Tensile Strength

Specification	EXRAD® HVFX	Silicone Rubber
SAE J-1128	3,270 PSI	1,507 PSI

Higher tensile strength is an important feature both on-vehicle and also during harness fabrication as it represents resistance to deformation and penetration of sharp objects. Even minor compromises in the insulation can lead to failure and direct electrical short.

Champlain Cable has been using irradiation technology for over 45 years and is a world leader of irradiation cross-linking in the wire and cable industry. Our eight irradiation units are capable of cross-linking wires ranging from 26awg to 700MCM, (0.14mm^2 to 350mm^2) and cables with diameters up to 1.5 inches (3.8 cm).

You can review specifications and learn more about our ingenuity at www.champcable.com